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Patentanmeldung Nr. Patent application No. Demande de brevet n°

02077884.1

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R C van Dijk

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Application no.: 02077884.1
Demande no:

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Anmelder/Applicant(s)/Demandeur(s):

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Bezeichnung der Erfindung/Title of the invention/Titre de l'invention:
(Falls die Bezeichnung der Erfindung nicht angegeben ist, siehe Beschreibung.
If no title is shown please refer to the description.
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Non-linear picture processing

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Non-linear picture processing

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(38)

The present invention relates to picture signal processing and, in particular, but not exclusively, to adaptive improvement of picture quality.

Although high quality display devices are currently available for displaying, for example, video and computer-generated images, limitations nevertheless still exists particularly with digital displays such as LCD display panels and monitors. There is therefore recognition that there is further room for improvement in image quality and it is appreciated that a noticeable improvement to image quality could be brought about by achieving increases in color saturation. However, display devices commonly exhibit a maximum acceptable saturation value and it has been found to be the case that, while some areas of a displayed image, with particular colors, might well be at, or near, their maximum saturation value, other areas with different colors might still be someway below such maximum value.

Yet further, and particularly with current digital LCD monitors, relatively few picture adjustments are available to the user. Most frequently picture contrast and brightness can be adjusted, while saturation, hue and color temperature are less frequently available. In such digital displays, each pixel is driven by a triplet of values wherein each one represents the intensity of one of the three colors red, green and blue. However, due to the finite number of bits serving to represent each color value, the possible driving values are likewise limited. For example, in a 24-bit LCD display panel, each color can be driven with any value included within a range of 0 to 255. Thus, if there is an attempt, either through some form of picture processing, or indeed user control, to increase the output over the maximum allowed value, a clipping effect will therefore result causing all the driving levels over the threshold to be represented by the same value, i.e. the maximum saturation value. Thus, some picture detail quite clearly present in the input picture signal will therefore be lost through the amalgamations of the saturation levels caused by such clipping effect.

It is an object of the invention to enhance images. The invention is defined by the independent claims. The dependent claims define advantageous embodiments.

According to one aspect of the present invention, there is provided a method of non-linear processing of input picture signals characterized in that the non-linear processing is responsive to hue values of the input picture signals.

It is a particular advantage that the processing can serve to limit, or indeed avoid, any clipping of the output signal. This can be achieved by increasing the saturation up to a maximum level, at which clipping does not yet take place. Use is made of amongst others the hue values to determine this maximum level.

The invention has the advantage that, for example, color saturation of the output picture signals can thereby be controlled in a manner avoiding loss of picture-detail, since the color saturation is increased more for picture areas showing low saturation levels than for picture areas showing high saturation levels. The clipping effect discussed above is therefore advantageously avoided.

The set of input parameter values preferably comprises the saturation values, as an increase of the saturation considerably enhances the image to be displayed.

Alternatively adaptations of the brightness values can be applied. By suitably combining adaptations of saturation values as well as brightness values, there will be no undesired discoloration of the image.

A simple method of non-linear processing is raising the parameter values to a certain power. By selecting a power depending on the hue values the non-linear processing takes into account that the output picture signals show no (or a negligible) clipping effect.

The non-linear processing can further be refined (in the sense of, for example, maximizing the saturation, while avoiding or minimizing clipping), by taking into account the maximum saturation value S_{max} during the non-linear processing of the saturation values.

It is advantageous if the maximum saturation value S_{max} is dependent on the hue values or the output parameter values corresponding to the brightness (preferably depending on both hue values as well as output brightness values).

The powers used in the non-linear processing can also be made dependent on the content of the image, represented by a histogram of one or more sets of input parameter values. This is a further refinement to adapt the non-linear processing in such a way that, for example, saturation is further increased, while clipping effects are further minimized.

In case of input picture signals representing real-time video information, the video information can be considered as a sequence of images. Each image has its own histogram. The powers can be adapted directly depending on the content of the histogram, or alternatively, a more gradual change can be applied by adapting the powers based on an

averaging over several images (low-pass filtering) of the changes of the powers. In this way irregularities are avoided, which would arise from sudden large changes of the powers from image to image.

Thus, it should be appreciated that, with the present invention, the saturation and/or the brightness of each pixel within a display can be modified in a non-linear manner that serves to introduce significant enhancements where the input picture signals are having low saturation values, less significant enhancements where the saturation values of the input signals are close to their maximum limits, and no changes where the input signals are having maximum saturation values already.

These and other aspects of the invention will be apparent from and elucidated with reference to the drawings in which:

Fig. 1 is a basic block diagram of a system embodying the general concept of the present invention;

Fig. 2 is a schematic block diagram showing the system of Fig. 1 in further detail;

Fig. 3 is a schematic block diagram illustrating one particular implementation of the non-linear saturation processing block of Fig. 2;

Fig. 4 is a schematic block diagram of non-linear luminance processing block of Fig. 2;

Fig. 5a illustrates a graphical representation between maximum saturation and brightness for a given hue;

Figs. 5b to 5d illustrate suitable values for intermediate parameters.

Figs. 6a and 6b comprise schematic block diagrams of a hardware implementation of the saturation bound evaluation block of Fig. 2; and

Fig.7 illustrates suitable values for the power γ_h.

Fig. 8 illustrates suitable values for the other power γ_Y.

Turning first to Fig. 1, there is provided a generic block diagram illustrating a system 10 arranged for driving a display device in accordance with an embodiment of the present invention and which includes a non-linear processing engine 12 arranged to receive red, green and input pictures signals 14 and, once processed, to output red, green and blue output picture signals 16 for a display device such as an LCD panel. The operation of the non-linear processing engine 12 is controlled by means of a microcontroller 18 which is itself

responsive to signals from a histogram evaluator 20 which samples the red, green and blue input picture signals 14 or parameters derived from these signals (not shown). In this illustrated example, the histogram evaluator 20 works on brightness, saturation and hue values of the input picture signals as will be illustrated further with reference to Fig. 2. Of course, the figures illustrate merely one possible implementation of the present invention. The picture signals 14 represent an image composed of a matrix of rows and columns of pixels. The red, green and blue picture signals 14, 16 comprise in a digital format information about the red, green and blue color components of the pixels of an image. In case of real-time video signals, these signals are handled as a sequence of images. To each of these images the processing can be applied.

In Fig. 2, there is illustrated, in somewhat greater detail, one possible embodiment of Fig. 1 and each of the processing blocks illustrated therein is now discussed in turn.

A first converter block 22 serves to convert the Red R, Green G, Blue B input picture signals 14 into Brightness Y, Hue H, and Saturation S parameter values.

In the illustrated embodiment, this block can be split functionally in two sub-blocks, i.e. a linear transformation accomplished through a matrix followed by a non-linear block.

Through the linear block Brightness Y and chromaticity coordinates C_r, C_b are calculated for all pixels as follows:

$$\begin{bmatrix} Y \\ C_r \\ C_b \end{bmatrix} = \begin{bmatrix} a_{11}a_{12}a_{13} \\ a_{21}a_{22}a_{23} \\ a_{31}a_{32}a_{33} \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix},$$

wherein the matrix $a_{i,j}$ comprises a predetermined set of parameters, which depend on the color coordinates of the display device to be driven. This computation can be executed in hardware by using three multipliers and three adders for each row.

The saturation S and hue values H for a pixel are then defined through the following formulae:

$$S=(C_r^2 + C_b^2)^{1/2}$$

$$H=\tan (C_r/C_b).$$

These functions can be implemented in several ways for example by using Look Up Tables (LUTs) and/or hardware interpolators.

A non-linear saturation processing block 24 is arranged to receive maximum saturation values S_{max} and the saturation values from the converter 22. How the maximum saturation value S_{max} is determined for a pixel will be explained later. In the illustrated embodiment a non-linear function in the form of a gamma function is employed as follows:

$$S' = S_{max}(S/S_{max})^{\gamma_h},$$

wherein S' is the output parameter of the output picture signals 16 corresponding to the saturation and γ_h the power used in this non-linear processing.

The transfer function can be rearranged in this form:

$$S' = 2^{\gamma_h[\log_2(S)-\log_2(S_{max})]+\log_2(S_{max})}$$

This function can be implemented in several ways, for example using LUTs and multipliers. One possible embodiment is illustrated in Fig. 3.

Firstly the logarithm of the saturation S and maximum saturation value S_{max} is determined in respective logarithmic blocks 302, 301. Next, the results are subtracted in subtractor 303. The output of the subtractor 303, being $Log_2(S) - Log_2(S_{max})$, is multiplied with the power γ_h in multiplier 304. The output of the multiplier 304 is added to the output $Log_2(S_{max})$ of block 301 in adder 305. The output of the adder 305 is used as power in exponential block 306, wherein the number two is raised to this power. The result, present at the output of the exponential block 306, is the output saturation value S'.

A saturation bound evaluation block 34 receives both the hue values H from the converter 22 and the output brightness value Y' from the luminance-processing block 32.

The graph of Fig. 5a illustrates a typical relationship between the maximum saturation values S_{max} and the brightness values Y for a given Hue value H. Intermediate parameters m_1, m_2 and Y_t are functions of the hue values H. These values can be readily obtained from a LUT. Intermediate parameters m_1 and m_2 are defined as a tangent of the respective angles α_1, and α_2 as shown in Fig. 5a;

$m_1 = tg(\alpha_1)$

$m_2 = tg(\alpha_2)$

In Fig. 5b, 5c, 5d suitable values for the respective intermediate parameters m_1, m_2 and Y_t are provided. These suitable values have experimentally been found in a situation, where the input parameter values are available in an eight bit digital format (resulting in 256 possible different values) and the matrix a_{ij} contains following values:

$a_{11} = 66$	$a_{12} = 129$	$a_{13} = 25$
$a_{21} = -38$	$a_{22} = -74$	$a_{23} = 112$
$a_{31} = 112$	$a_{32} = -94$	$a_{33} = -18$

When applying this matrix a_{ij}, the minimum brightness value Y_{min} (as shown in Fig. 5a) is equal to zero, while the maximum brightness value Y_{max} amounts to 220.

A block diagram of a possible hardware implementation of the saturation bound evaluation block 34 is given in Fig. 6a. A first branch calculates the function $(Y_{max} - Y').m_2$ by means of first subtractor 601 and first multiplier 602. A second branch calculates the function $(Y'-Y_{min}).m_1$ using second subtractor 603 and second multiplier 604. Comparator 605 determines whether Y' is larger or smaller than Y_t. If Y' is larger than Y_t multiplexer 606 selects $(Y_{max} - Y').m_2$ as output. If Y' is smaller than Y_t then multiplexer 606 selects $(Y'-Y_{min}).m_1$ as output. In this way the output of the multiplexer 606 corresponds to the desired maximum saturation values S_{max} as function of the output brightness values Y' as shown in Fig. 5a.

The intermediate parameters m_1, m_2 and Y_t are obtainable from LUTs, which receive the hue value H as input (not shown in Fig. 6a). These LUTs contain the intermediate parameters as shown in the graphs of Figs. 5b, 5c, 5d.

An alternative blockdiagram of a possible hardware implementation of the saturation bound evaluation block 34 is given in Fig. 6b. The comparator 610 determines again whether Y' is larger than Y_t:

If no, the multiplexers 611, 612, 615 select as output the input values present at the input indicated by the dotted lines inside the multiplexers 611, 612, 615.

- If yes, the multiplexers 611, 612, 615 select the input values present at the other inputs.

As a result, at the output of the subtractor 613 will be present $(Y'-Y_{min})$, or respectively $(Y_{max}-Y')$.

The multiplier 614 multiplies the mentioned outputs of subtractor 613 with m_1, respectively m_2 depending on the output of comparator 610.

The multiplexer 615 selects m_1, respectively m_2 depending on the output of comparator 610. The resulting output of the multiplier 614 is again the desired maximum saturation value S_{max}:

$$S_{max} = (Y'-Y_{min})m_1, \text{ if } Y' \leq Y_t$$

$$S_{max} = (Y_{man}-Y')m_2, \text{ if } Y' > Y_t$$

As mentioned before, the intermediate parameters are obtainable from LUTs.

A γ_h LUT block 26 receives the hue values H from the converter 22. The γ_h value can comprise a function of hue. In this way it is possible to apply different color saturation processing depending on the hue values H. This can be realized easily using a LUT. An example of suitable values of the power γ_h as function of the Hue values H is given in Fig. 7. The power γ_h, shows larger values (close to one) within a limited range of hue values H. This limited range includes, for example, the hue values H around 145 corresponding to skin colors. The human eye is very sensitive to these colors and an increase of saturation would result in "unnatural" images. By reducing the degree of non-linear processing (by selecting powers closer to one) for these skin colors, this problem is avoided. Outside the limited range a considerable "boosting" of the colors is obtained by applying, for example, a value of 0.7 for γ_h.

Turning back to Fig. 2, a non-linear luminance processing block 32 is arranged to receive the brightness value Y from the converter 22.

In this embodiment a non-linear function, using another power γ_Y is applied wherein the output brightness values Y' is provided by the function:

$$Y' = Y^{\gamma_Y}$$

The transfer function can be rearranged in below form:

$$Y' = 2^{\gamma_Y [\log_2 Y]}$$

Above function can, for example, be realized as shown in the hardware block diagram of Fig. 4. The logarithm of the input brightness value Y is determined in the logarithmic block 401. The output of the logarithmic block 401 is multiplied with the other power γ_Y in multiplier 402. The output of multiplier 402 is used as power in the exponential block 403 to raise the number two to this power. The result present at the output of the exponential block 403, is the output brightness value Y'. An alternative for above hardware block diagram is to apply LUTs.

In Fig. 2, a γ_Y LUT Block 28 also receives the hue values H from the converter 22. The γ_Y value can also comprise a function of hue, and so it is possible to apply different brightness processing depending on the hue values H. This can be easily realized by way of an appropriate LUT. An example of suitable values of the other power γ_Y as function of the hue values H is given in Fig. 8. The other power γ_Y shows a value close to one within a limited range of the hue values H (around 145). Again, in this range the degree of non-linear processing is reduced (or made zero) in order to avoid unnatural skin colors. Outside this range, the other power γ_Y has preferably a value larger than one, for example 1.2.

In Fig. 2, a YHS to RGB converter 30 comprises the last block in the signal flow path and serves to convert the output parameter values Y', S', H to the output picture signals $R'G'B'$.

This block can be implemented by cascading a non-linear transformation function for obtaining output chromaticity coordinates Cr' and Cb' from the output saturation values S' and hue values H, followed by a linear transformation converting these coordinates in output picture signals R', G' and B'.

The formulae for calculating output coordinates Cr' and Cb' are:

$$Cr' = S' \sin(H) \qquad Cb' = S' \cos(H)$$

The functions sin(H) and cos(H) can be implemented through Look Up Tables and interpolators.

Further, the values of output picture signals R', G', B', can be calculated by multiplying Y', C_r', C_b' by an appropriate matrix b_{ij} as shown below.

$$\begin{bmatrix} R' \\ G' \\ B' \end{bmatrix} = \begin{bmatrix} b_{11} b_{12} b_{13} \\ b_{21} b_{22} b_{23} \\ b_{31} b_{32} b_{33} \end{bmatrix} \begin{bmatrix} Y' \\ C_r' \\ C_b' \end{bmatrix},$$

wherein the matrix b_{ij} comprises a predetermined set of parameters depending on the color coordinates of the display device. The function requires three multipliers and three adders for each matrix row.

The non-linear processing can also be made dependent on the distribution of the input parameter values Y, S, H of an image. This distribution can be evaluated by using a histogram evaluator 20 as shown in Fig. 2. The evaluator 20 receives the input parameter values Y, S, H and determines the number of occurrences of combinations (triplets) of input values Y, H, S in an area (a "window") of an image (or in the whole image).

Depending on the distribution the powers γ_Y and γ_h can be adapted in respectively the γ_Y LUT 28 and γ_h LUT 26 via micro-controller 18. As a result the degree of non-linear processing can be adapted depending on the distribution. Since the main goal is to adapt for a given hue value H the color saturation of an area of an image, a suitable parameter to use is the average saturation value $\bar{S}(Y)\big|_H$, which is a function of the input brightness value Y.

This average saturation value $\bar{S}(Y)\big|_H$ as function of input brightness values Y can be derived from the histogram $\Omega(Y,H,S)$ as follows:

$$\bar{S}(Y)\Big|_H = \sum_i S_i \Omega\big|_H (Y, S_i),$$

wherein Ω_H is the histogram for a given hue value H, i is an index for the range of possible input saturation values S' and S_i is the i-th possible input saturation value. In case of 8 bits digital input picture signals, the range of i is 256.

A refinement can be applied by taking into account a weighing factor $W(Y,H)$, that weights the average saturation values $\bar{S}(Y)\big|_H$ depending on the maximum possible saturation values for a given input brightness value Y.

Taking into account the weighing factor W(Y,H), the weighed average saturation value becomes:

$$\bar{S}'(Y)\big|_H = W(Y,H)\,\bar{S}(Y)\big|_H = \frac{\bar{S}(Y)\big|_H}{S_{max}(Y,H)}$$

As next step a parameter $\psi|_H$, being a weighed average hue saturation value for a given hue value, can be calculated from the expression:

$$\psi\Big|_H = \sum_j Y_j\,\bar{S}'(Y_j)\big|_H ,$$

wherein j is an index for the range of possible input brightness values Y.

The weighed average hue saturation value $\psi|_H$ related to an area of an image can be used to adapt the degree of non-linear processing by adapting the power γ_h.

In case of video information with changing areas in an image or changing images, the value $\psi|_H$ is determined for each image of the video information. The current value $\psi|_H$ is compared with a user adjustable target value $\psi_T|_H$.

If the current value $\psi|_H$ deviates from the target value $\psi_T|_H$, then an error signal, proportional to the difference of the 2 values is used to adapt the power γ_h. By applying a low pass filtering on the error signal, abrupt changes of the power γ_h due to changing video information are avoided.

In this way disturbing effects are avoided, when the output picture signals are displayed on the display device.

It should be noted that the above-mentioned embodiments illustrate rather than limit the invention, and that those skilled in the art will be able to design many alternative embodiments without departing from the scope of the appended claims. In the claims, any reference signs placed between parentheses shall not be construed as limiting the claim. The word "comprising" does not exclude the presence of elements or steps other than those listed in a claim. The word "a" or "an" preceding an element does not exclude the presence of a plurality of such elements. The invention can be implemented by means of hardware comprising several distinct elements, and by means of a suitably programmed computer. In the device claim enumerating several means, several of these means can be embodied by one and the same item of hardware. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

CLAIMS:

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1. A method of non-linear processing of at least one set of input parameter values of input picture signals so as to produce output picture signals with output parameter values, characterized in that the non-linear processing is responsive to hue values of the input picture signals.

2. A method as claimed in Claim 1, wherein the non-linear processing involves the steps of determining a power γ_h depending on the hue values, and raising a saturation-related input parameter value S to the power γ_h.

3. A method as claimed in Claim 2, further comprising the step of adapting the power γ_h based on histogram data derived from the input parameter values.

4. A method as claimed in Claim 1, wherein the non-linear processing involves the steps of determining an power γ_Y depending on the hue values, and raising a brightness-related input parameter value to the power γ_Y.

5. A method as claimed in Claim 4, further comprising the step of adapting the power γ_Y based on histogram data derived from the input parameter values.

6. A method as claimed in Claim 2, wherein the non-linear processing of the saturation related input parameter value S depends on maximum saturation values S_{max}.

7. A method as claimed in Claim 6, wherein the maximum saturation values S_{max} depend on the hue values.

8. A method as claimed in Claim 6, wherein the maximum saturation values S_{max} depend on a brightness-related output parameter value.

9. A method as claimed in Claim 6, wherein a saturation-related output parameter value S' is substantially determined by the equation:

$S' = S_{max}(S/S_{max})^{\gamma_h}$.

10. A method as claimed in Claim 3, wherein for a predetermined hue value the power γ_h is adapted based on a weighed, average saturation value of the input picture signals, representing pixels in a window of an image.

11. A method as claimed in Claim 10, wherein for a predetermined hue value the power γ_h for a current window is adapted depending on the histogram data of the current and/or a previous window.

12. An apparatus comprising picture processing circuitry for carrying out the method as claimed in claim 1.

ABSTRACT:

The present invention provides for a method of picture processing for a display device characterized by the steps of processing input picture signals (R,G,B) in a non-linear manner so as to produce output picture signals (R',G',B') for the device, such non-linear processing being responsive to parameters (Y,S,H) of the input picture signals (R,G,B).

Fig. 1

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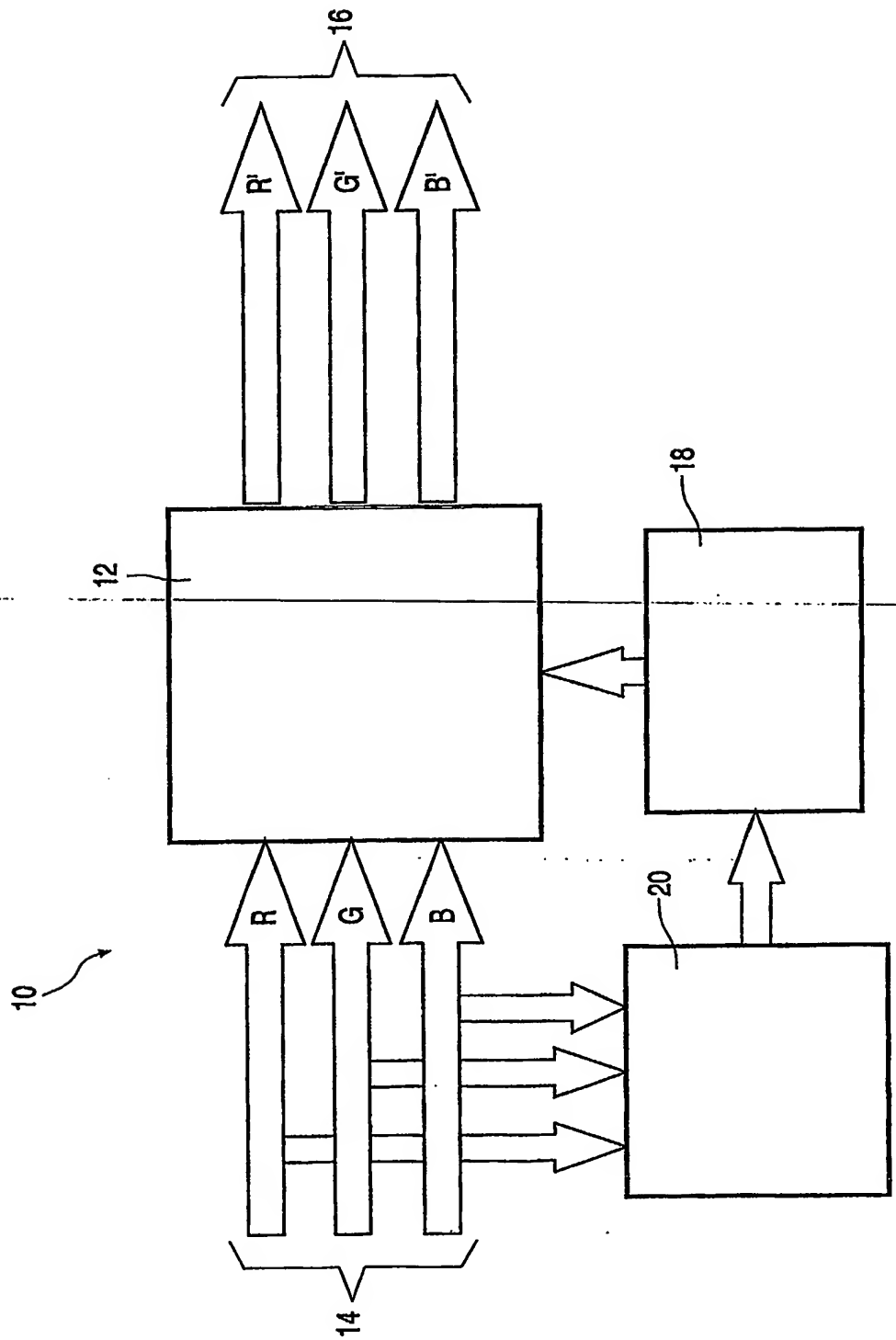
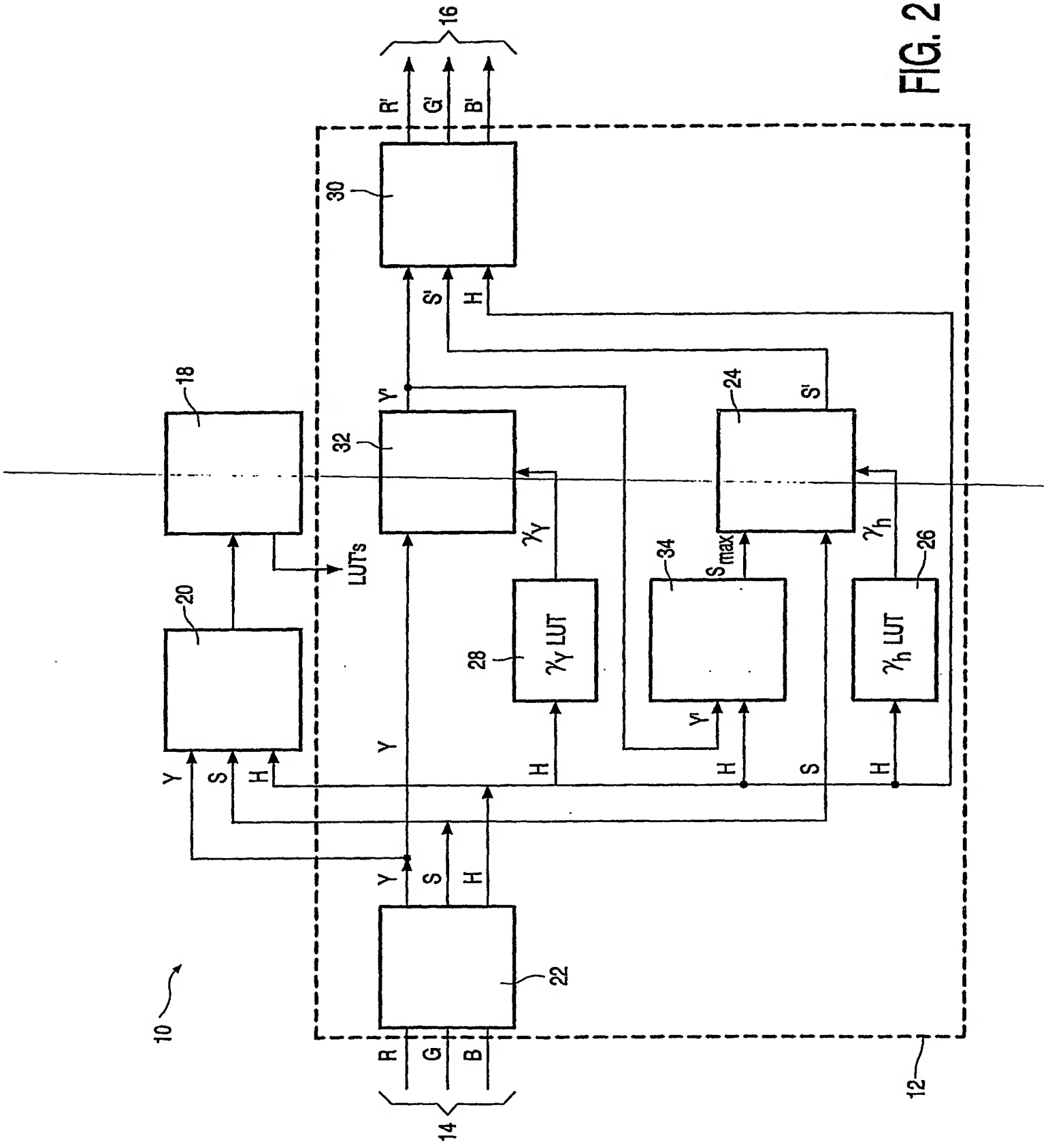


FIG. 1

FIG. 2


16
R'
G'
B'
30
S'
H
18
Y'
32
24
S'
LUTs
γγ
γh
20
28
γγ LUT
34
Smax
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γh LUT
Y
S
H
Y'
Y
S
H
22
10
R
G
B
14
12

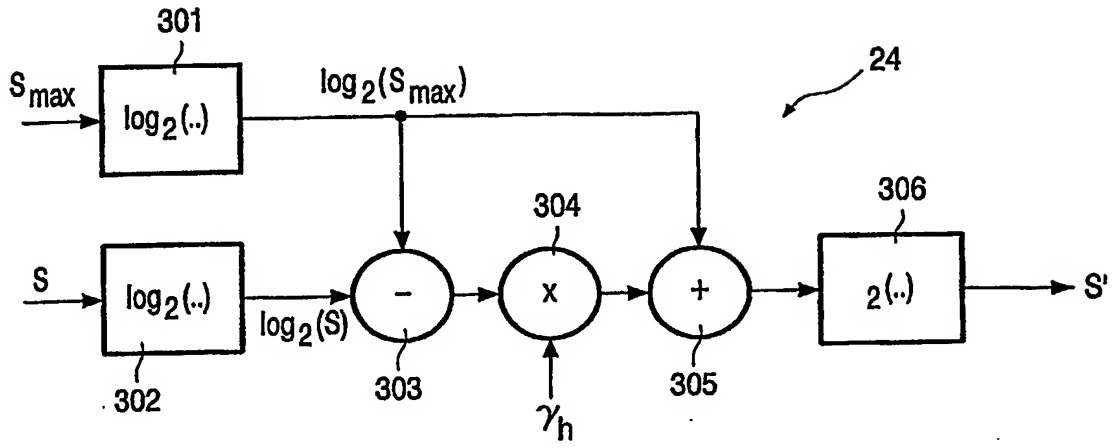

FIG. 3

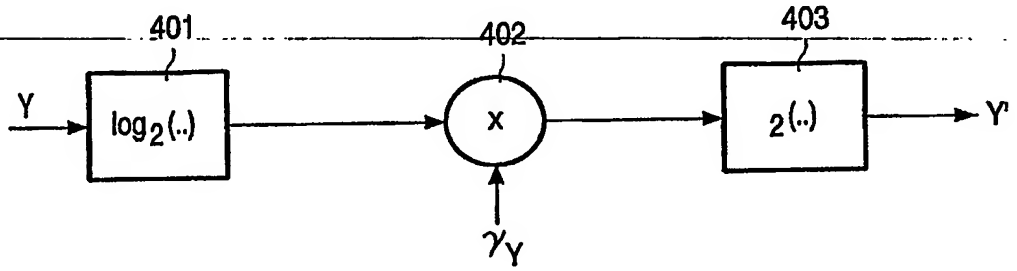

FIG. 4

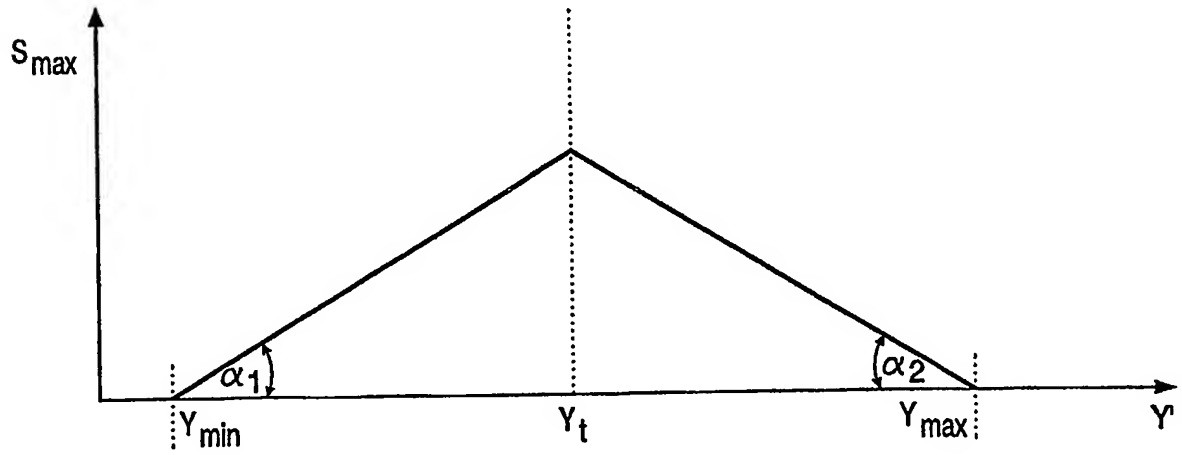

FIG. 5a

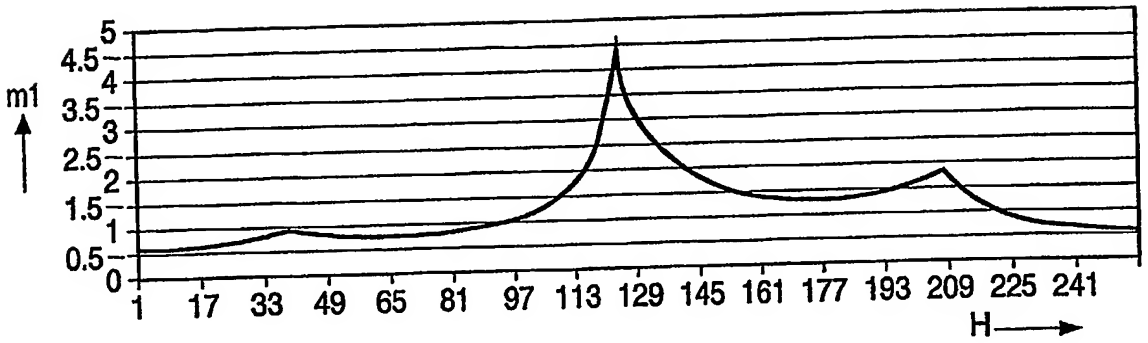

FIG. 5b

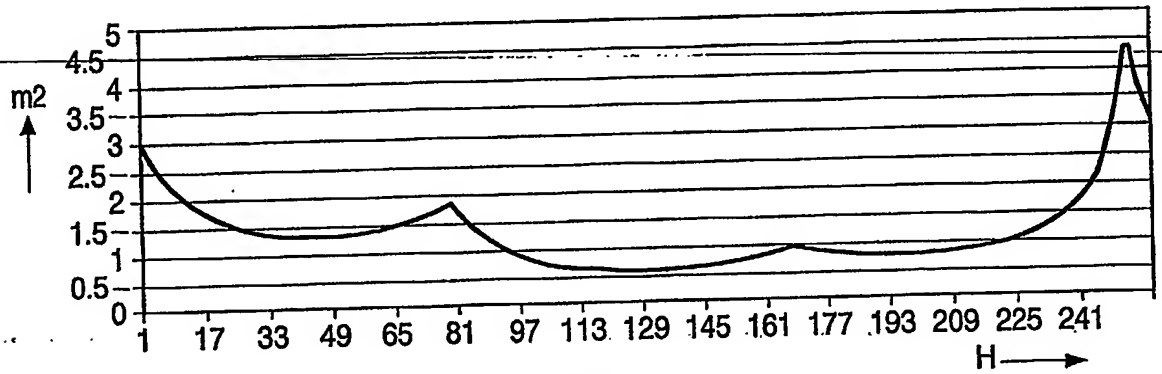

FIG. 5c

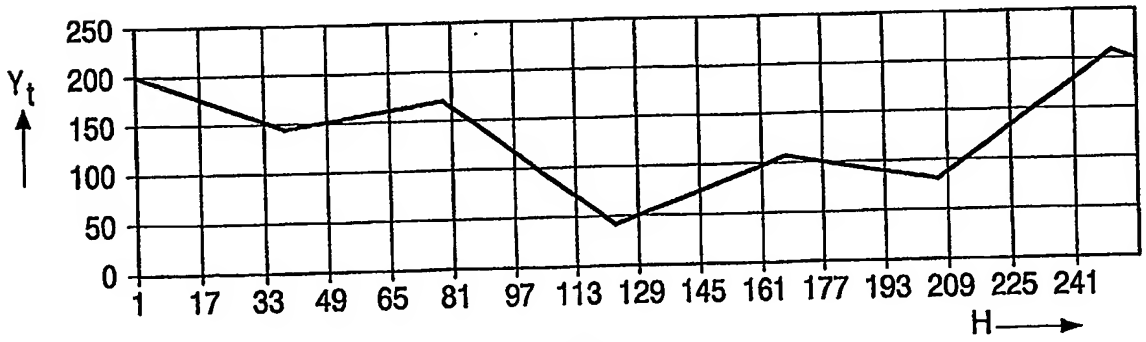

FIG. 5d

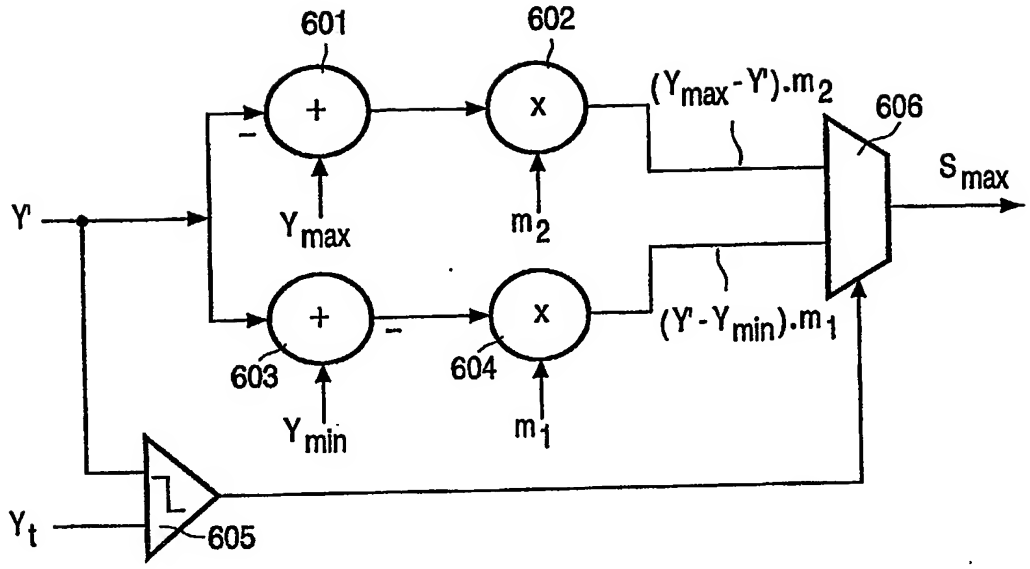
601
602
+
x
$(Y_{max}-Y').m_2$
606
S_{max}
Y'
Y_{max}
m_2
+
x
$(Y'-Y_{min}).m_1$
603
604
Y_{min}
m_1
Y_t
605

FIG. 6a

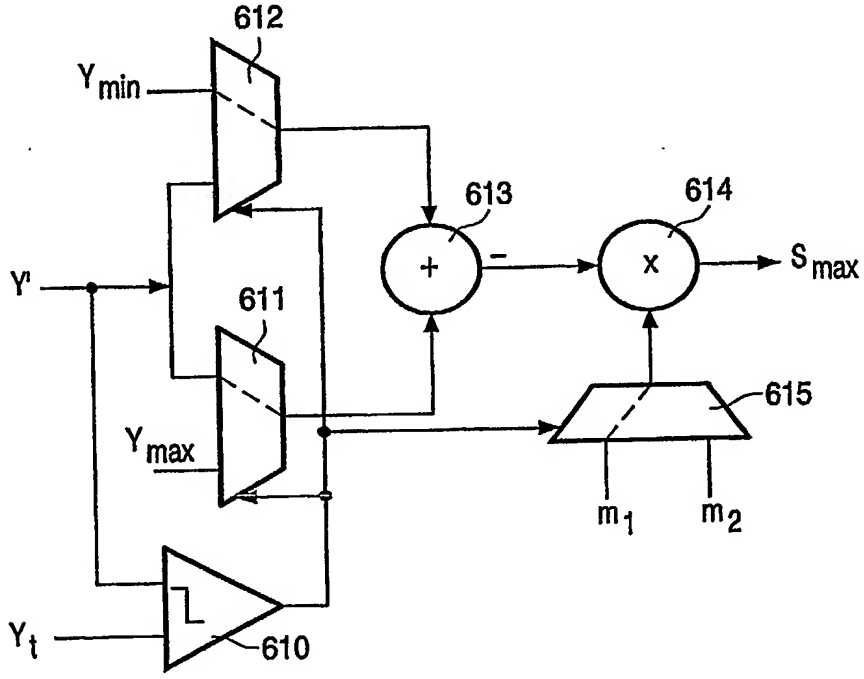
612
Y_{min}
613
614
+
x
S_{max}
Y'
611
615
Y_{max}
m_1
m_2
Y_t
610

FIG. 6b

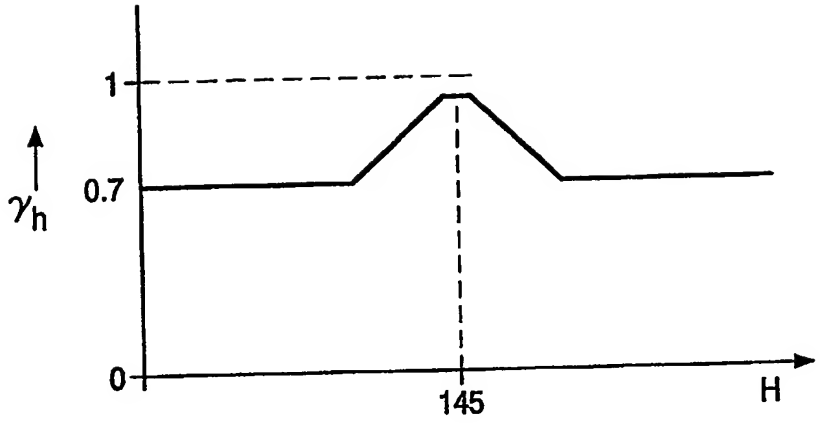

FIG. 7

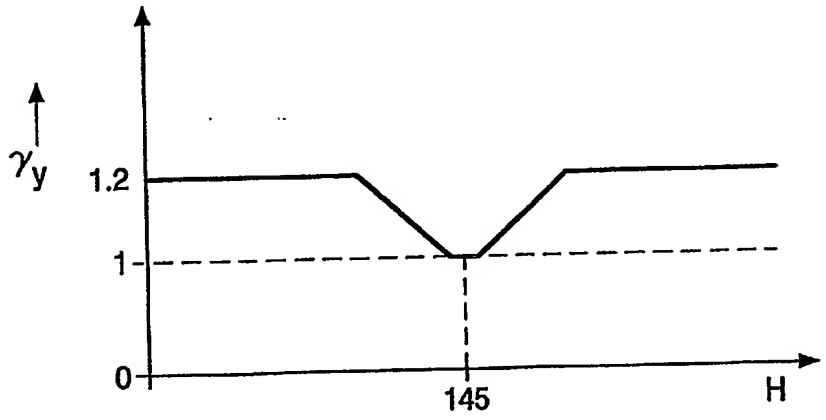

FIG. 8

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